Evaluation of Vibration Monitoring of HFO Purifiers in the Klaveness Fleet

NTNU
Norwegian University of Science and Technology

Odin Dypdalen Kjærvik

Supervisor: Prof. Ingrid Bouwer Utne (NTNU) & Co-Supervisor: Christian Bjanger Skjelbred (Klaveness Operation)

Torvald Klaveness

Problem

In 2018, Klaveness launched a Condition-Based Monitoring (CBM) pilot project on two of their combination carriers, MV Balboa (built in 2016) and MV Ballard (built in 2017). Here, offline and manual vibration monitoring equipment was installed on a considerable amount of rotating machinery, mostly compressors, pumps and engines. Klaveness want this to take them from a Preventive Maintenance (PM) regime to a Condition-Based Maintenance (CBM) regime.

When installing online monitoring equipment in the entire fleet, Klaveness plan to reduce the number of equipment being monitored, to ensure that it actually adds value. One of the systems that is being considered for online monitoring are the heavy fuel oil (HFO) purifiers. This is a system with redundancy, but also with a history of incidents that could have been prevented. The objective of the thesis is to evaluate whether it would be beneficial to equip the HFO purifiers with vibration monitoring equipment.

Introduction

Historically, maintenance in the shipping industry has been either corrective or pre-planned. I.e., after a breakdown or calendar-based, based on equipment running hours, or distance travelled, respectively. This is still the case today. However, condition-based maintenance (CBM) and predictive maintenance (PdM) is becoming increasingly more popular to increase asset reliability and decrease maintenance costs. Unlike corrective and planned maintenance, CBM and PdM are based on the measurement of different equipment parameters to decide if or when maintenance should be performed, so-called condition monitoring (CM) [7].

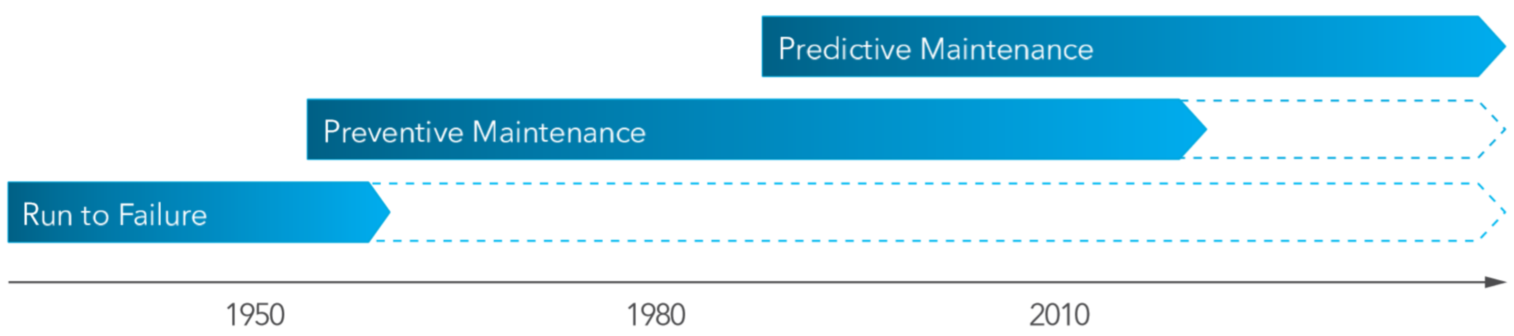

Fig. 1: Evolution of maintenance practices. From [7].

Vibration monitoring (VM) is by far the most used method for CM, constituting about 58% of the total CM market [1, 8]. It is considered to be one of the two main techniques for obtaining information about the internal conditions of machines, especially for rotating equipment [2, 5]. It can for instance be used for both online and offline monitoring, and it is suitable for pinpointing the location of impending failures. It is also possible to apply multiple signal processing techniques to the vibration signals. Hence, even weak indications of faults, or developing faults, can be extracted from the signals [2]. Several successful implementations of vibration monitoring can be seen in [3, 10, 11].

An example of vibration analysis from the CBM pilot can be seen Figure 2 below. Vibration measurements indicating unbalance (red) is compared to measurements conducted after preventive measures were taken (blue).

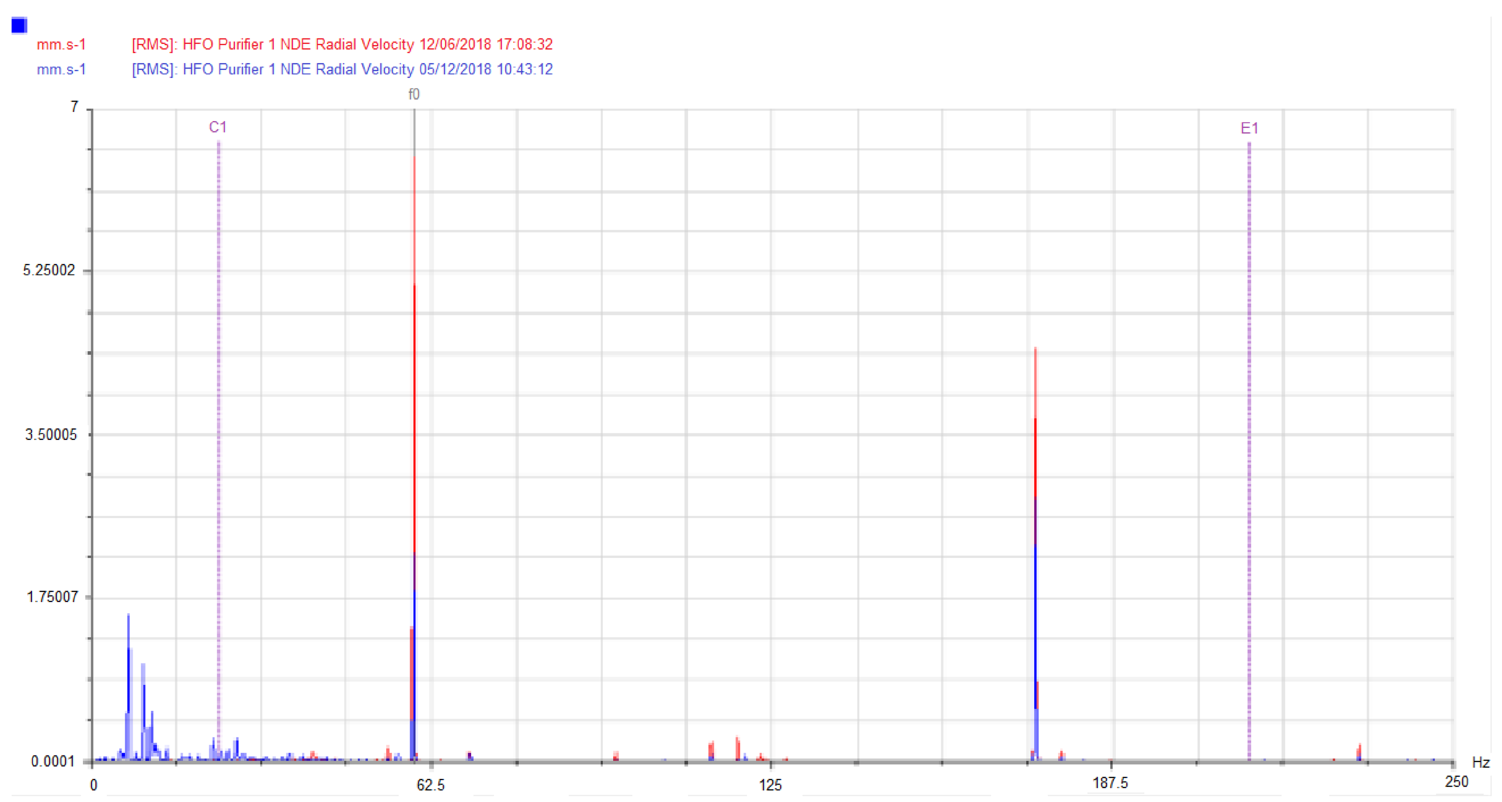

Fig. 2: Velocity spectrum on the non drive end (NDE) of the Electric Motor of the Purifier. Red: 12.06.2018, Blue: 05.12.2018.

Condition Monitoring Pilot

The CBM pilot was initiated to help build knowledge and better understand the benefits and limitations of CBM and PdM. They want to utilize the experience from the pilot to decide on equipment maker and scope for CM onboard their fleet.

After the pilot period, a qualitative review of the equipment monitored was conducted to evaluate where condition monitoring would add value when being installed on vessels in the fleet. The decision not to install monitoring equipment on approx. half of the machinery from the pilot is solely qualitative. It is based on the criticality of the system for the operation of the ship, whether it is redundant or not, how expensive unexpected failures might be and if they could have been detected by vibration monitoring, the size of the equipment, and the incident history of the equipment. The many incidents that could have been detected by VM is the main reason for a more thorough evaluation of whether to install VM equipment on the HFO purifiers.

Method

Failure Modes, Effect and Criticality Analysis: FMECA is a systematic technique for failure analysis [9]. The function of an FMECA is to "consider each major part of the structures, systems, and components (SSC), how it may fail (the mode of failure), and what the effect of the failure on the SSC would be (the failure effect)" [6]. I.e., the main objective of an FMECA is to highlight failure modes with relatively high probabilities and severity of consequences, thus allowing corrective actions to be directed where it will produce the greatest value. As a result, an FMECA is a set of both critical and non-critical component failures.

The method has been chosen as it is a helpful tool to, amongst others, identify and prevent safety hazards, minimize loss of product performance or performance degradation, develop PM plans for in-service machinery and equipment, and develop online diagnostic techniques [4]. The analysis is carried out in the online Relyence FMEA tool.

Incident Analysis: The author has systematically gone through and organized approximately fifty incident reports related to HFO purifiers across the Klaveness fleet from 2015-2019. The work has been carried out in Microsoft Excel. The incident analysis has provided useful input for the FMECA analysis.

Results

An excerpt from the FMECA analysis is given in Figure 3 below. Additionally, the preliminary incident analysis has shown that out of the 42 incidents directly related to HFO purifiers, 21 (i.e. 50%) could potentially have been discovered by vibration monitoring.

Component	Function	Failure Mode	Cause	Local Effect	Global effect	Probability of Occurrence
Separator	Separate water, foreign matter and sludge from HFO	Clogged separator bowl	Bad quality of bunkered HFO (contaminated)	HFO purifier not working	No standby separator available in case of failure.	May happen once a year

	Consequences				
Hidden/Evident	Safety	Environment	Availability	Material damage and ops. Cost	Compliance breach
Hidden	Minor personal injury/not fit for duty	Minor effect (on vessel only)	Considerable impact, 1-7 days	Minor material damage, $50,000-500,000	Loss of reputation

Fig. 3: FMECA excerpt for failure mode "Clogged separator bowl".

Further Work

Until the submission deadline, the FMECA will be completed to assess the most critical failure modes, with respect to severity and frequency of occurrence, of the system. Then, the incident reports will be more thoroughly analysed. It is of great interest to find out whether there are any connections between failures, their frequency and causes, and if they potentially could have been revealed by vibration monitoring. If time, other measures to avoid or reduce the consequences of failures, either as an alternative or supplement to vibration monitoring, will be looked into and discussed.

The lack of results thus far is due to events beyond the control of the author. The problem definition was not fixed before the end of April, and the author did not receive the necessary data from Klaveness before the beginning of May.

References

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